Instrumentation of a racing bicycle for outdoor field testing and evaluation of the cyclist's comfort perception

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ABSTRACT

Together with the use of high stiffness materials for racing bicycle frames such as carbon fibre reinforce plastics (CFRP), the need for more comfortable bicycles has risen. Bicycle designers have introduced many attempts to improve the cyclist's comfort, but it still remains difficult to quantify the comfort gain and what the effect is on the bicycle dynamics. This work proposes a method to measure comfort during cycling and therefore sensors must be designed which fit on the bicycle. Sensors measuring force, acceleration and velocity are necessary to adequate measuring comfort. The final result is a bicycle instrumented with 16 sensors, together with real time data acquisition and data storage.

INTRODUCTION

During the improvement of racing bicycle over the years, the bicycle frame geometry has hardly changed but the frame material has evolved from simple construction steel to a high performance composite material. Nowadays, many racing bicycles have a bicycle frame made of CFRP. This frame material meets the needs of the rider to bicycle stability, frame stiffness and weight reduction. But, this high frame stiffness is in contrast with the ability of the frame to absorb shocks from the road pavement. That is why frame constructers have looked to counteract this lack of comfort. Some attempts have already been tried out but it remains difficult to estimate the effect it really has on the cyclist's comfort perception and bicycle handling. Evaluation of human comfort to vibrations is already introduced in automotive and other industries, the whole-body vibration ISO2631 standard (Mechanical vibration and shock - evaluation of human exposure to whole-body vibration -- Part 1: General requirements, 1997) or the BS6841 is often used then. These standards relate the acceleration level at the contact interface between man and machine to human comfort. The higher the acceleration level, the lower the comfort. Besides these whole-body vibration methods, the absorbed power method is introduced to assess vibrational comfort (Wilson, 2004). The latter method requires data on contact force and contact velocity between man and machine. In this work, both methods are used to evaluate the cyclist's comfort perception to bicycle vibrations coming from the road roughness. In order to have real world data from road excitations and bicycle dynamics, experiments on comfort evaluation are performed outdoor. This requires a stand-alone system which can be used for outdoor field testing. This includes an instrumented bicycle with sensors, real time data acquisition and data storage.

RESULTS AND CONCLUSIONS

Comfort evaluation by means of the whole-body vibration method requires acceleration measurement at the contact points between the cyclist and the bicycle, thus at the handlebar and the seat. At each contact point acceleration is measured in two orthogonal directions, in the x- and z-direction respectively the driving- and vertical direction. Standard available IEPE accelerometers with a 100mV/g sensitivity are selected.

More challenging is the design of sensors necessary for comfort evaluation based on the absorbed power method. Both force and velocity must be measured at the handlebar and the seat. If possible, the sensors should fit any racing bicycle so comparison of different bicycles to their comfort is possible without the need for a new design each time. Analogue to the acceleration measurement, force and velocity should be measured in two orthogonal directions. The contact force is measured by placing strain gauges near the handlebar and the seat. Four active strain gauges are placed in a Wheatstone bridge configuration so that the measured output signal only varies with the magnitude of the force applied and not with the position of the force. This concept is of major importance at the handlebar where the hands can freely move along the handlebar. Measuring force at the saddle needs the design of an insert at which strain gauges can be placed, see Fig. 1. This separate insert is necessary to fulfil the requirements of having a modular concept and good load sensitivity in both orthogonal directions. Finite Element calculations, as shown at Fig. 2, confirm that the designed insert fulfils requirements (i) to strength, (ii) that both force components are decoupled and (iii) good load sensitivity is achieved. Force measurement at the handlebar does not require any insert as with the saddle, strain gauges can be positioned immediately at the handlebar (Fig. 3). At both sides of the steer, horizontal and vertical force can be measured.

Vibration velocity is obtained by integrating the acceleration signal from the accelerometers at the handlebar and the seat. To avoid the drift in the velocity signal due to integration, the acceleration signal is filtered with a high pass filter with a low cut-off frequency.

After calibration of the force sensors and mounting all sensors at the bicycle; these sensors are connected to a data acquisition system which is then connected to a high performance laptop for real time processing and storage of data. In future work, outdoor field tests are performed and parameters such as road pavements and tyre pressure are examined on their influence at the riding comfort of the cyclist. Comfort will be evaluated with the whole-body vibration method as with the absorbed power method to see if both lead to the same findings.

Fig. 1: Insert below saddle, instrumented with strain gauges

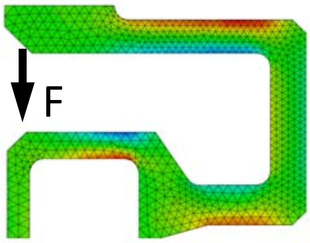

Fig. 2: FE analysis of saddle insert, bending stress due to vertical force

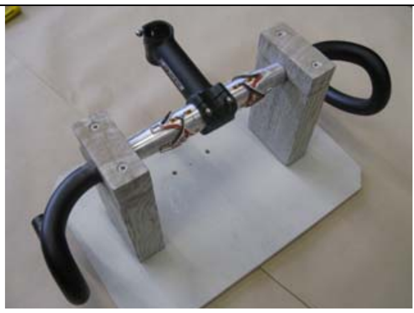

Fig. 3: Instrumented handlebar for force measurement

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